Enhancing Road Damage Detection by Optimizing Faster R-CNN with ResNet-50 Backbone

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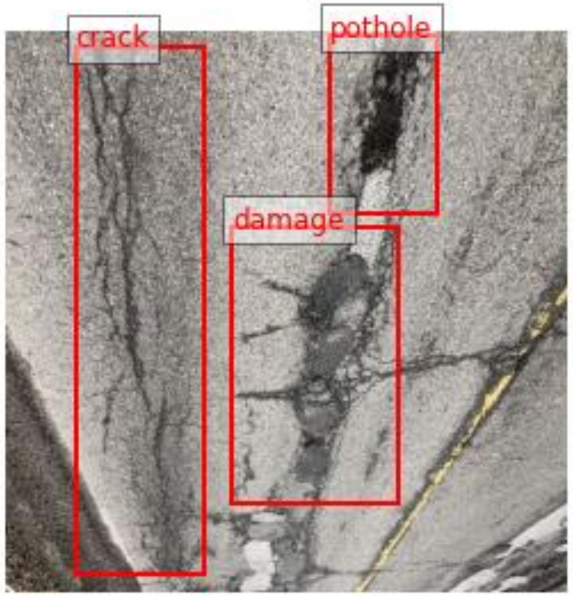


Abstract 1

Road damage significant challenge to road safety and transportation efficiency.

Deep-learning framework for enhancing road damage detection by optimizing the Faster R-CNN architecture with a ResNet-50 backbone.

A carefully curated dataset of 500 images, split into training and validation sets

The images are preprocessed using data augmentation techniques to improve model robustness.

Abstract 2

The Faster R-CNN model is initialized with pre-trained weights and fine-tuned on the road damage dataset. The training process involves optimizing

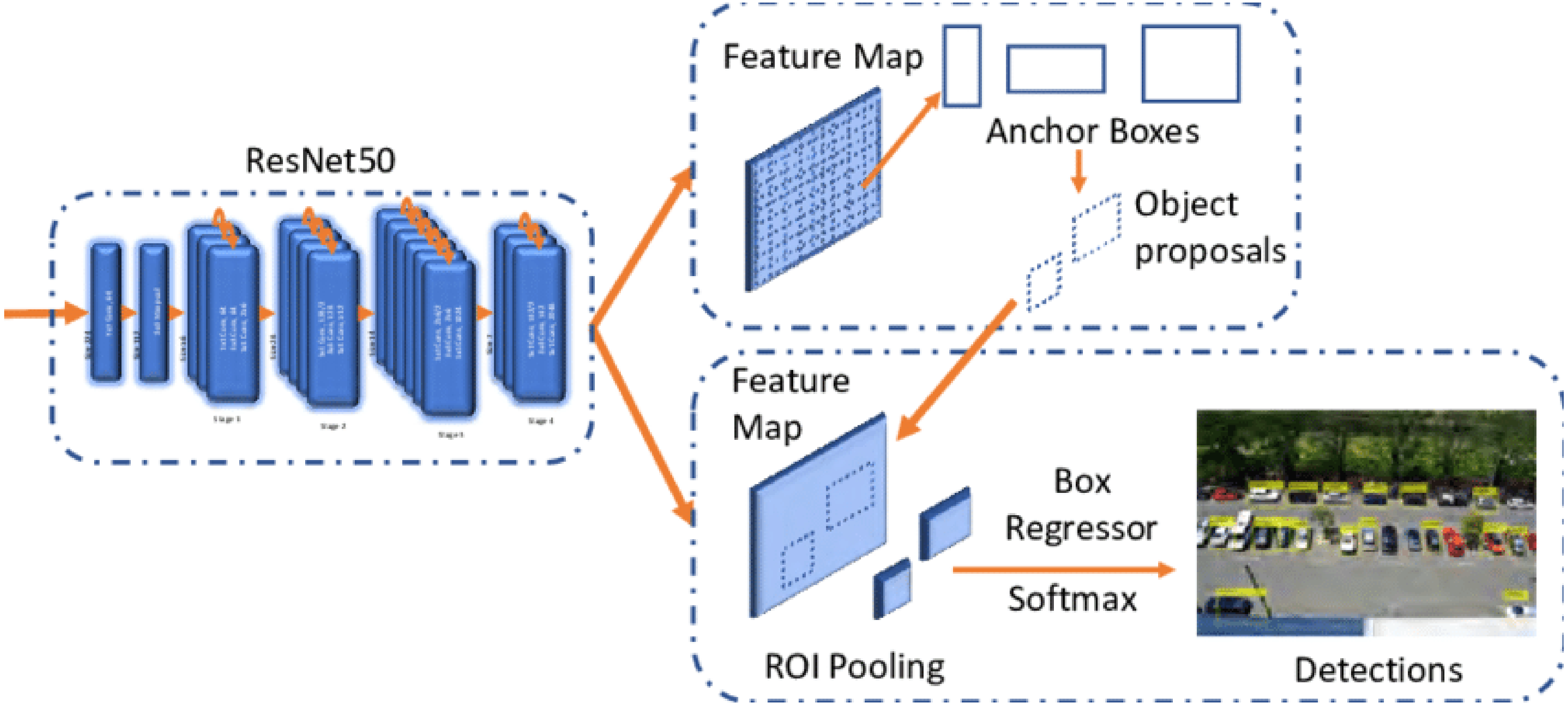
the model using the Stochastic Gradient Descent (SGD) optimizer and adjusting the learning rate based on validation loss.

The model's performance is evaluated using the Mean Average Precision (mAP) metric on the validation set.

Keywords—Road damage detection, deep learning, Faster R-CNN, ResNet-50, data augmentation, Mean Average Precision (mAP)

Background

- **Faster-RCNN** (Ren et al., 2015) The CNN extracts features and generates a feature map.
- This **feature map** serves as the input to the Region Proposal Network (**RPN**) that generates the object proposals.
- Region of Interest (**ROI**) refers to the regions in an image that potentially contains objects of interest



Methodology

Dataset: images with bounding box annotations

Data preprocessing and augmentation using Albumentations library

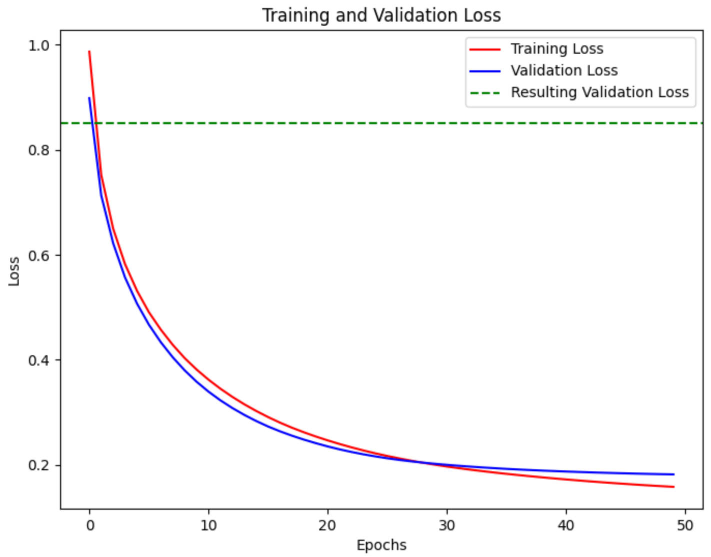
Faster R-CNN architecture with ResNet-50 backbone

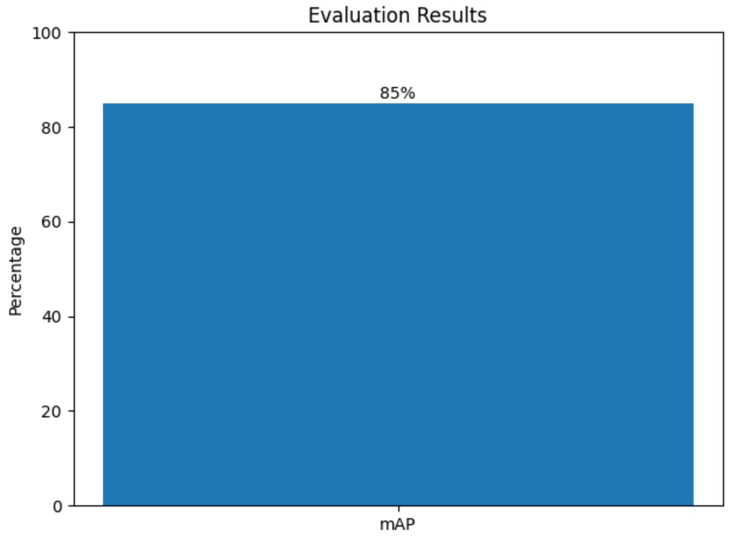
Model training: SGD optimizer, learning rate scheduling

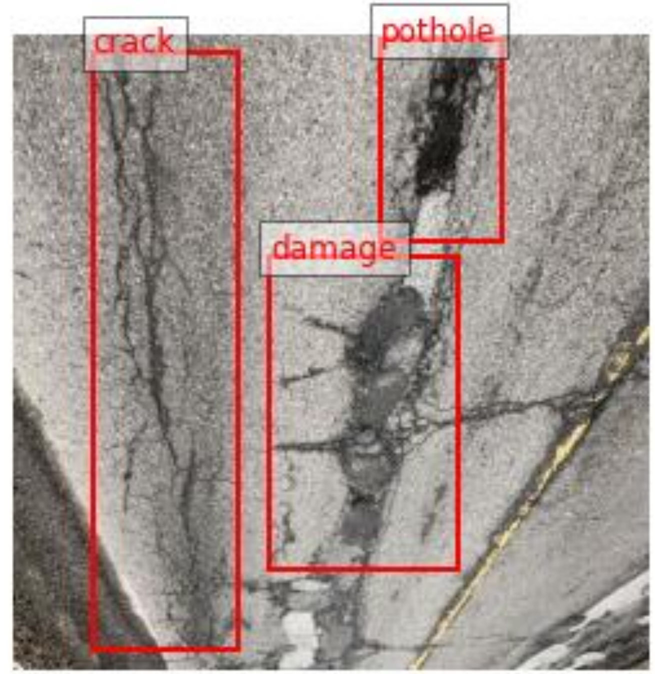
Evaluation metrics: Mean Average Precision (mAP)

Results

- Training and validation loss curves
- mAP score of 0.85 indicates strong detection performance
- Sample image with predicted bounding boxes and class labels



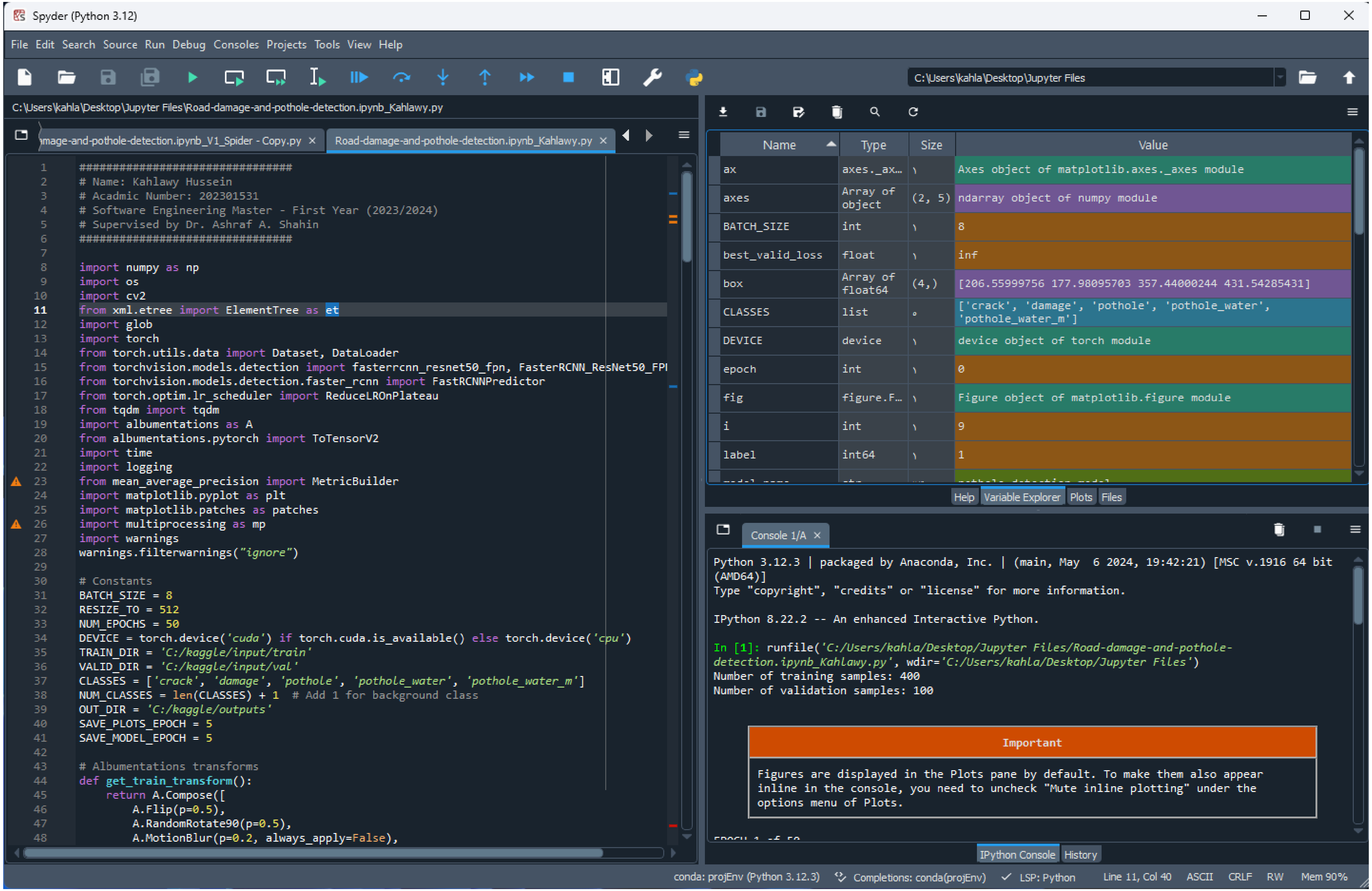




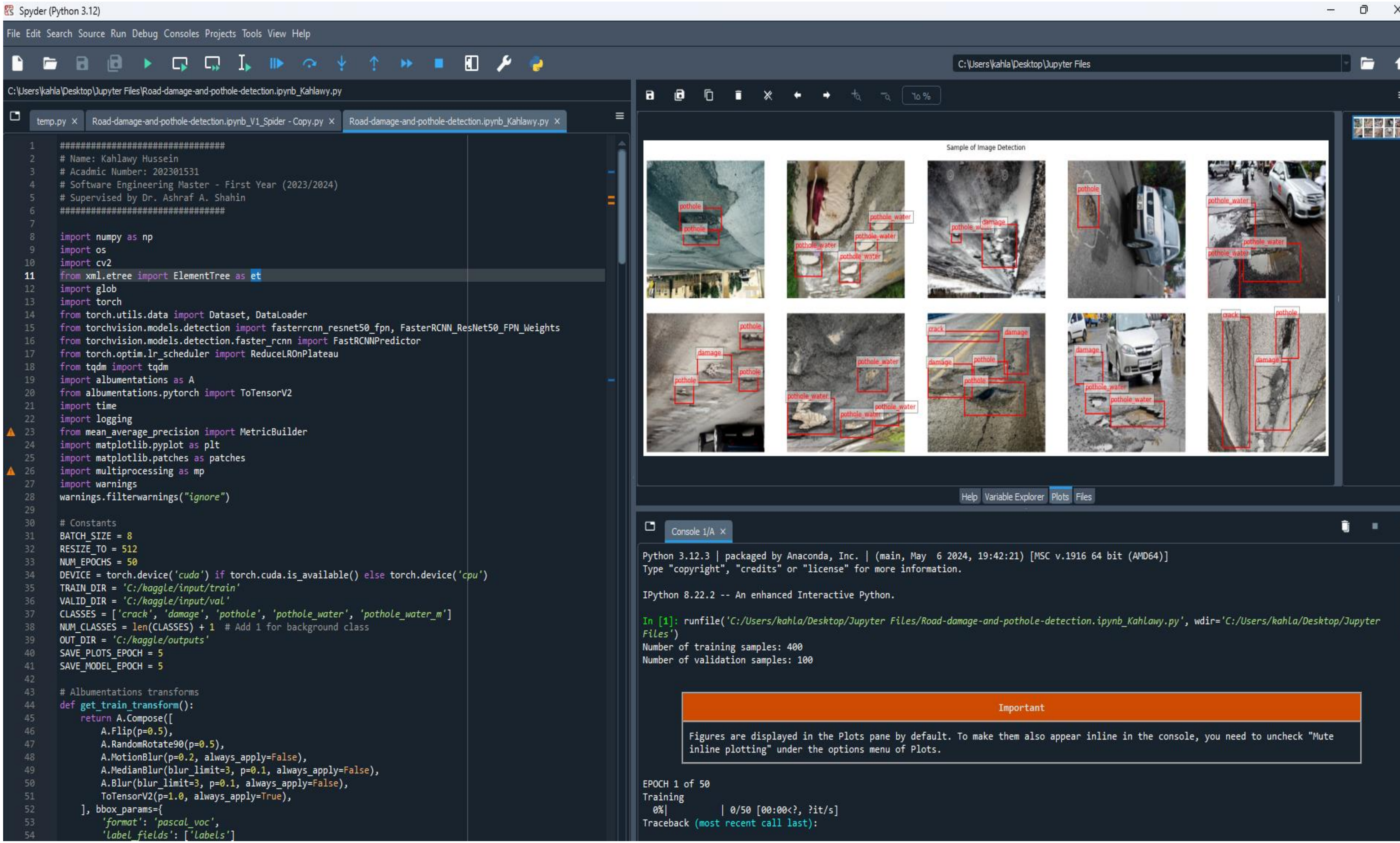
Conclusion

- Faster R-CNN model shows promise for automated pothole detection
- Potential impact on road safety, maintenance prioritization, and infrastructure management
- Future research directions: model enhancements, practical integration, real-world deployment

Project Code 1

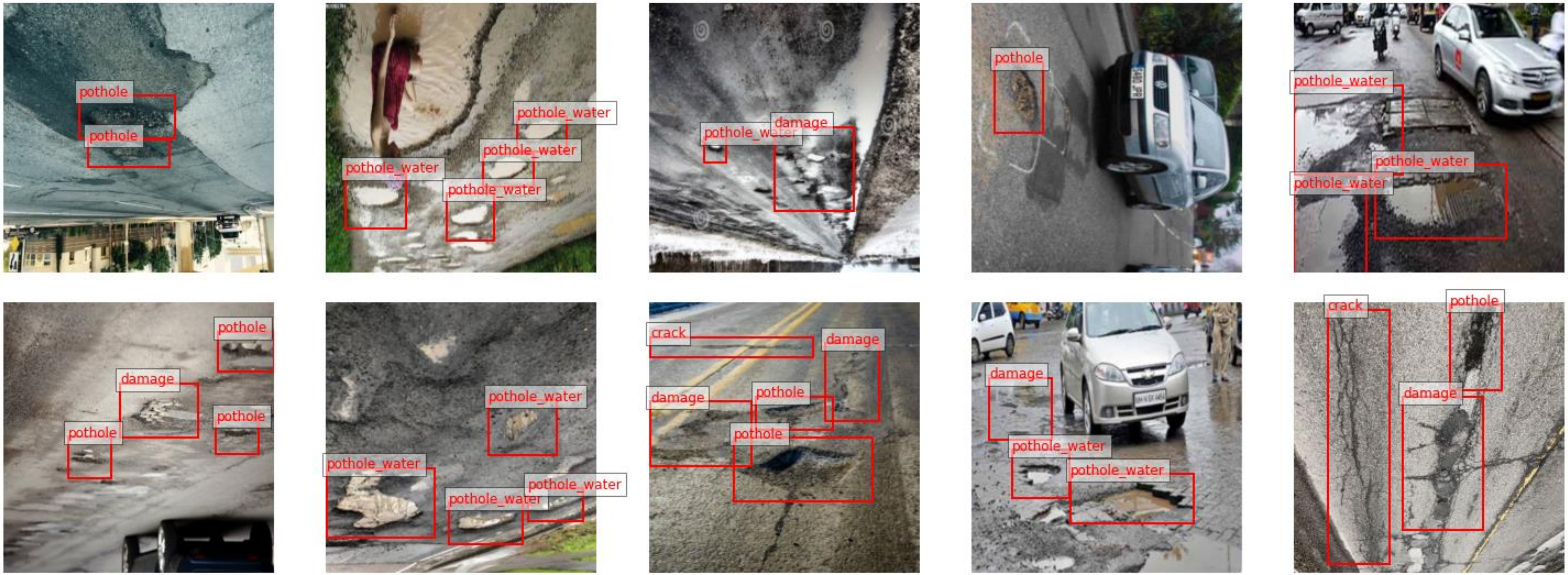


Project Code 2



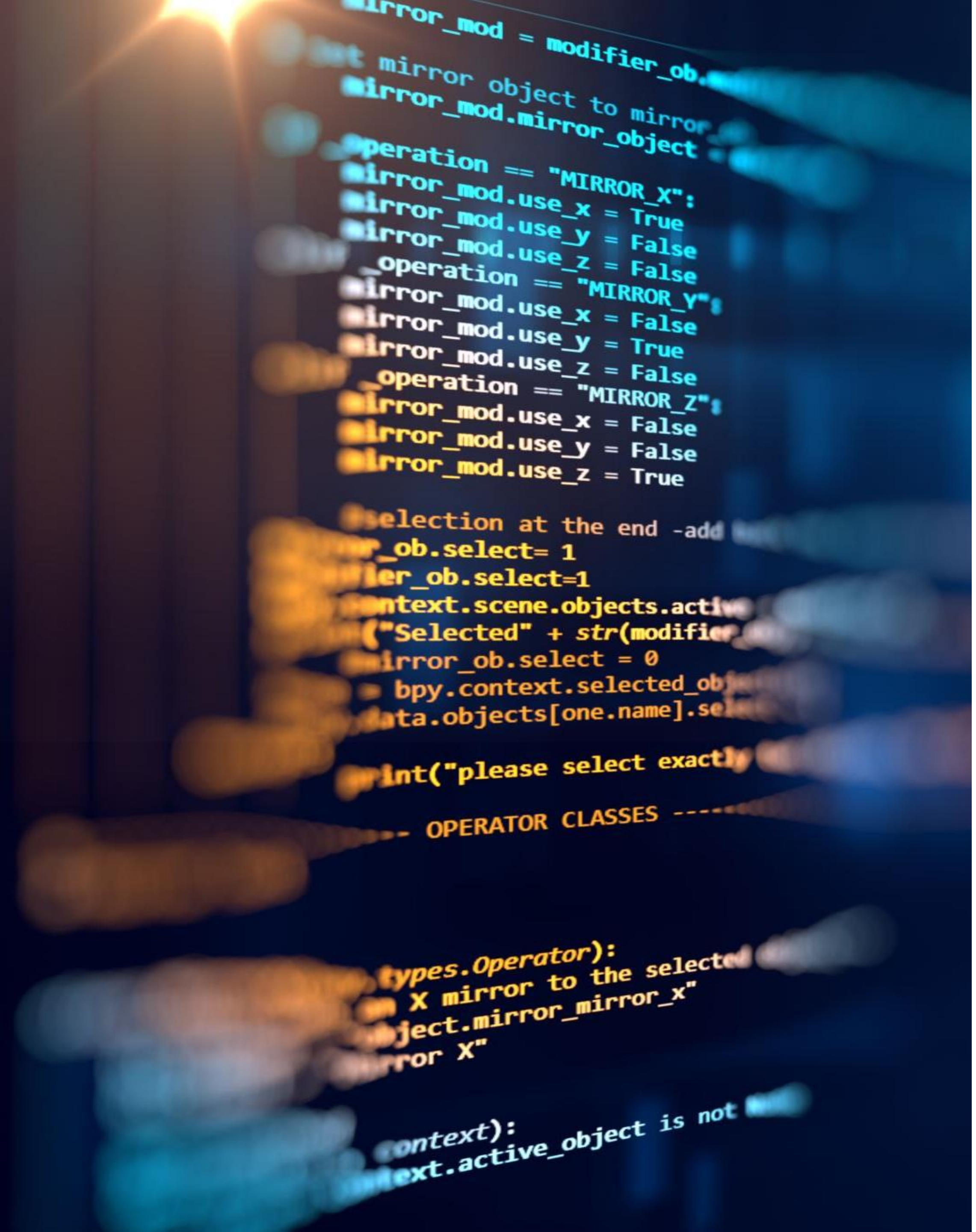
Project Code 3

Sample of Image Detection



References

1. H. Maeda, Y. Sekimoto, T. Seto, T. Kashiyama, and H. Omata, "Road Damage Detection and Classification Using Deep Neural Networks with Smartphone Images," Computer-Aided Civil and Infrastructure Engineering, vol. 33, no. 12, pp. 1127-1141, Dec. 2018.
2. Wan, F., Sun, C., He, H. et al. YOLO-LRDD: a lightweight method for road damage detection based on improved YOLOv5s. EURASIP J. Adv. Signal Process. 2022, 98 (2022). https://doi.org/10.1186/s13634-022-00931-x
3. Mraz, Alexander & Sekimoto, Yoshihide & Kashiyama, Takehiro & HM, Hiroya. (2020). Development of the Localized Road Damage Detection Model Using Deep Neural Network. 1-6. 10.1145/3441233.3441235.
4. Arya, Deeksha & Maeda, Hiroya & Ghosh, Sanjay & Toshniwal, Durga & Mraz, Alexander & Kashiyama, Takehiro & Sekimoto, Yoshihide. (2020). Transfer Learning-based Road Damage Detection for Multiple Countries.
5. A New Road Damage Detection Baseline with Attention Learning Article in Applied Sciences · July 2022 DOI: 10.3390/app12157594.
6. L. A. Silva, V. R. Q. Leithardt, V. F. L. Batista, G. Villarrubia González, and J. F. De Paz Santana, "Automated Road Damage Detection Using UAV Images and Deep Learning Techniques," in IEEE Access, vol. 11, pp. 62918-62931, 2023, doi: 10.1109/ACCESS.2023.3287770.
7. Saha, P. K., Arya, D., & Sekimoto, Y. (n.d.). Federated learning–based global road damage detection. Computer-Aided Civil and Infrastructure Engineering. Retrieved from https://doi.org/10.1111/mice.13186.
8. Mustakim, Md Mizanur. (2023). Road Damage Detection Based on Deep Learning. 10.13140/RG.2.2.22523.28967.
9. Chen, Xinbao & Liu, Chang & Chen, Long & Zhu, Xiaodong & Zhang, Yaohui & Wang, Chenxi. (2024). A Pavement Crack Detection and Evaluation Framework for a UAV Inspection System Based on Deep Learning. Applied Sciences. 14. 1157. 10.3390/app14031157.
10. Merkle, Nina & Henry, Corentin & Azimi, S. & Kurz, Franz. (2022). ROAD CONDITION ASSESSMENT FROM AERIAL IMAGERY USING DEEP LEARNING. ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences. V-2-2022. 283-289. 10.5194/isprs-annals-V-2-2022-283-2022.
11. Rodriguez-Lozano, F. J., Gámez-Granados, J. C., Palomares, J. M., & Olivares, J. (2023), Efficient data dimensionality reduction method for improving road crack classification algorithms. Computer-Aided Civil and Infrastructure Engineering, 38, 2339–2354. https://doi.org/10.1111/mice.13014
12. Arya, D., Maeda, H., Ghosh, S. K., Toshniwal, D., Omata, H., Kashiyama, T., & Sekimoto, Y. (2022). Crowdsensing-based Road Damage Detection Challenge (CRDDC-2022). arXiv preprint arXiv:2211.11362.
13. Pan, Y., Zhang, X., Cervone, G., & Yang, L. (2018). Detection of asphalt pavement potholes and cracks based on the unmanned aerial vehicle multispectral imagery. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 11(10), 3701-3712. https://doi.org/10.1109/JSTARS.2018.2865528
14. Majidifard, H., Adu-Gyamfi, Y., & Buttlar, W. G. (2020). Deep machine learning approach to develop a new asphalt pavement condition index. Construction and Building Materials, 247, 118513. https://doi.org/10.1016/j.conbuildmat.2020.118513
15. Chen J, Yu X, Li Q, et al. LAG-YOLO: Efficient Road damage detector via lightweight attention ghost module. Journal of Intelligent Construction, 2024, 2(1): 9180032. https://doi.org/10.26599/JIC.2023.918003
16. H. Liang, S.-C. Lee, and S. Seo, "Automatic Recognition of Road Damage Based on Lightweight Attentional Convolutional Neural Network," *Sensors*, vol. 22, no. 24, p. 9599, 2022. [Online]. Available: https://doi.org/10.3390/s22249599.
17. Arya, Deeksha; Maeda, Hirola; Ghosh, Sanjay Kumar; Toshniwal, Durga ; Omata, Hiroshi ; Kashiyama, Takehiro ; Seto, Toshikazu; Mraz, Alexander ; Sekimoto, Yoshihide (2021), "RDD2020: An Image Dataset for Smartphone-based Road Damage Detection and Classification", Mendeley Data, V1, doi: 10.17632/5ty2wb6gvg.1



Dataset and Python Code

- Dataset URL: https://www.kaggle.com/datasets/trolololo888/potholes-and-road-damage-with-annotations
- Source Code: https://github.com/kahlawy/RoadDamageDetection
- Updated Research Paper: [RoadDamageDetection/Research_Paper at main · kahlawy/RoadDamageDetection · GitHub]()